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Experimental Investigation on Fibre Reinforced Concrete Using Waste Plastics and Different Mineral Admixtures

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Abstract. Use of Fibre Reinforced Concrete (FRC) is one of the ways of overcoming the low tensile strength of concrete. Both organic and inorganic fibers can be made use in the production of FRC. On the other hand, the use of waste plastic is causing a serious environmental pollution since the plastic don't deteriorate. Such waste plastic can be reused in the form of fibres to produce waste plastic FRC. Further, flyash, microsilica and redmud are another industrial waste materials adding to environmental pollution. These waste materials are having cementatious properties and can be used along with waste plastic fibres in concrete to reduce their detrimental effect on mother earth. Therefore in this paper an attempt is made to assess the suitability of waste plastic FRC for construction purposes when different percentages of flyash, microsilica and redmud are introduced. Various strength properties such as Compression, Tension, Flexure and Impact are studied along with workability characteristics. Based on the obtained results the industrial wastes such as flyash, microsilica, redmud and also waste plastic fibres can be used in the production waste plastic fibre reinforced concrete composite material.

Keywords: Concrete composite, waste plastic, mineral admixtures, strength properties.

1. Introduction

The concept of combining more than two materials to obtain a composite is not new to the Civil Engineer. Fibers have been used to reinforce brittle materials since ancient times. The use of straw to strengthen sun-baked bricks and stabilize their dimensional instability has been practiced for centuries. In olden days, horsehair was used to reinforce plaster and more recently asbestos fibres are being used to reinforce Portland cement [1]. From straw in bricks and horsehair in plaster to asbestos in Portland cement, history is constantly undergoing a process of rebirth through new applications of different basic materials.

The idea of strengthening of concrete by including fibres was first put forward by Porter in 1910. But the development of this material took progress in 1963, when Romualdi and Batson published their classical paper on the subject. The authors proved that strengthening of crack in concrete can be increased by spacing the fibers closer to each other, which act as crack arresters. Also, it was conclude that the increase in strength is inversely proportional to the square root of fibres spacing [2]. Since then, there has been a wave of interest in fibre reinforced concrete and several interesting experiments have been carried out all over the world using different kinds of fibres.

When two different materials with contrasting of mechanical properties are combined together a new two phase composite material is formed. In an ideal two-phase composite the strong phase helps to improve the strength of week phase [3]. Usually, the two-phase composite material is got by combining one material of greater tensile strength and modulus of elasticity with another material of relatively low modulus of elasticity. The high strength material is more or less finally divided and evenly distributed or dispersed in a matrix and then mixed with the low modulus material. So, the whole material withstands the loading, which would have otherwise reputed the weaker material easily [4].

Cement concrete is an area in which the civil engineer has applied the idea of composite materials by combining cement paste and aggregates [5]. Conventional reinforced concrete becomes two phase composite only after cracking i.e. when the reinforcing bars hold the cracked concrete matrix. Alternatively, the use of short and closely spaced fibres in concrete is an ideal method of producing a two phase composite viz., in the sense that cracking strength can be increased by using closely spaced fibres which act as crack arresters [6]. Plastics are non biodegradable materials. They cannot be destroyed easily. Any effort of destroying it, again results in the environmental pollution [7]. Therefore, the best way to reduce environmental pollution due to plastics is by recycling and reusing them. As a result of growing quantity of wastes and need to save natural resources the recycling technology is gaining importance [8].

Therefore, the main objective of this experimental investigation is to assess the effectiveness of using waste plastics in concrete. The effect of addition of waste plastics in the form of fibres into the concrete has been studied in this experimental investigation along with different mineral admixtures. To understand the behaviour of waste plastic fibre reinforced concrete (WPFRC) composite thoroughly, strength properties such as compressive, tensile, flexure, impact strength and workability properties are studied.

2. Materials and Methodology

- Cement: The Ordinary Portland Cement of grade 43 confirming to IS: 8112-1989 is used.
- Coarse aggregates: The crushed stone aggregate of 10mm and down size confirming to per IS: 383-1970 and 2386-1963 (I, II and III) specifications. The fineness modulus of aggregate found from experiment is 1.9.
- Fine aggregates:A grade III sand confirming to IS: 383-1970 specification and fineness modulus 2.96 is used.
- Super plasticizer: A superplasticizer (Conplast SP-430) is used 1% by weight of cement.
- Flyash: The flyash confirming to IS: 3812-1981 specification is used in different percentages like 0, 5, 10, 25, 20 and 25 during mixing of concrete
- Microsilica: Microsilica-600 confirming to NZS 3122:1995 - Specification for Portland and Blended Cements is used in different percentages like 0, 2, 4, 6, 8, 10, and 12 during mixing of concrete.
- Redmud: The redmud used in experimentation was obtained from Indian Aluminum Company (INDAL) Belgaum. As the name itself suggests redmud is rust red colour. Its pH value exceeds 11 there by revealing its alkaline nature. The density of redmud is between 0.026-0.032 gm/mm3and with an atomic weight of 13
  Redmud was added 15% by weight of cement with different percentages of waste plastic fibres like 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5 during mixing of concrete
- Fibres: plastic pots, buckets, cans, drums and utensils are used to obtain waste plastic. The waste plastic fibres of thickness 1mm and width 5mm are obtained by cutting with the help of steel wire cutter. The waste plastic fibres of aspect ratio of 30 (thickness = 1mm, length = 30mm and breadth = 5mm) and 2.0% by weight of cement were added in the dry mix. The following table gives the physical properties of these fibres.

Table 1. Physical properties of waste plastic fibres.

Length (l), mm	Breadth (b), mm	Thickness (t), mm	Percentage of elongation	Tensile strength (MPa)	Modulus of elasticity (MPa)	Water absorption	Specific gravity
150	25	1	15.56	15.52	113.9	Nil	1.28

- Water: Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.
- Mix proportion**:** Mix design was done according to IS: 10262-1982 specification for M20 grade of concrete. Proportion of mix considered is 1: 1.435:2.46 with a water-cement ratio of 0.48 was obtained and used.

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3. Experimental procedure

3.1. Casting of Concrete Specimens

All the ingredients of concrete such as cement, fine aggregate (sand) and coarse aggregate (jelly) are weighed as per the proportion and dry mixed on a non-absorbent plat form. To this, the required quantities of waste plastic fibres were added by weight of cement and mixed thoroughly in dry state in required percentage. To this, the suitable quantity of water is added and mixed rigorously. The superplasticizers were added at the end to the wet mix by weight of cement followed by remixing homogeneously. All concrete moulds were cleaned from the existing concrete stain and oil was applied inside the moulds and then concrete is poured in them. A scoop is used to pour the fresh concrete into the mould. The moulds were filled with concrete in three layers with each layer being compacted by using standard tamping and using table vibrator. Finally, the specimens were given smooth finish and kept under wet gunny bags. After 24 hours, the specimens were remolded and transferred to curing tank where in they were allowed to cure for 28 days.

3.2. Testing of concrete specimens

The tests were conducted after the concrete specimens were cured for 28 days. The test procedure was carried out accordance with Indian standard: 516-1959 specification for compressive strength on standard size of specimens 150mm x 150mm x 150mm and flexural strength on standard size of specimens 100mm x 100mm x 500mm, indirect tensile strength test was carried out on standard size of specimens 150mm diameter x 300mm height accordance with Indian standard: 5816-1999 specification.

Table 2. Experimental test results on Compressive Strengthof waste plastic FRC with different flyash percentage.

Flyash (%)	Specimen	Weight (N)	Density (kN/m^3)	Failure load (kN)	Compressive strength (MPa)
0(Ref mix)	A	80.98	23.99	676.67	30.07
05	B	80.81	23.94	758.34	33.70 (+12)[a]
10	C	80.85	23.95	765.00	33.99 (+13)
15	D	79.77	23.63	731.67	32.51 (+08)
20	E	79.44	23.53	686.67	30.51 (+01)
25	F	78.70	23.32	650.00	28.88 (-04)

[a]The values in parenthesis indicates the percentage increase or decrease of compressive strength with respect to reference mix

Impact strength by drop weight method was conducted on Concrete specimen of size of 250mm width with 250mm breadth and thickness of 30mm were cast and cured for 28 days for impact strength. A mild steel ballwas dropped from a height of 1mexactly at the centre of impact specimen kept on the floor. Number of blows required to produce first crack and causefinal failure were noted. The impact strength was calculated as follows which is a function of number of blows.

$$\text{Impact energy} = mghN = w/g \times g \times h \times N = whN \text{ (N-m)}$$

where, m and w are the mass and weight of the ball dropped from 1m height, g is acceleration due to gravity, h is drop height 1m and N is number of blows at failure.

4. Experimental procedure

Compressive strength of concrete cubes with various percentages of flyash, mocrosilica, steel fibers and redmud are obtained after 28 days of curing. Table 2, 3 and 4 respectively gives the 28 days compressive strength respectively for various mixes of flyash, micro silica and plastic fibers along with 15% of redmud.

Table 3. Experimental test results on Compressive Strength of waste plastic FRC with different Microsilica percentage.

Microsilica(%)	Specimen	Weight (N)	Density (kN/m^3)	Failure load (kN)	Compressive strength (MPa)
0 (Ref mix)	A	76	22.52	0646.67	28.74
02	B	74	21.93	0796.67	35.40 (23)[a]
04	C	75	22.22	0803.34	35.70 (24)
06	D	74	21.93	0833.34	37.03 (29)
08	E	74	21.93	0913.34	40.59 (41)
10	F	75	22.22	1001.67	44.51 (57)
12	G	73	21.53	0893.34	39.70 (38)

[a]The values in parenthesis indicates the percentage increase of compressive strength with respect to reference mix

Table 4. Experimental test results on Compressive Strength of waste plastic FRC with 15% Red mud and different Fiber percentage.

Fibres (%)	Specimen	Weight (N)	Density (kN/m^3)	Failure load (kN)	Compressive strength (MPa)
0 (Ref mix)	A	88.67	26.27	526.67	23.40
0.5	B	86.34	25.72	553.34	24.58 (+05)[a]
1.0	C	86.34	25.57	570.00	25.33 (+08)
1.5	D	85.17	25.22	596.67	26.51 (+13)
2.0	E	83.84	24.84	646.67	28.73 (+23)
2.5	F	83.34	24.68	600.00	26.66 (+24)
3.0	G	83.00	24.59	552.67	24.58 (+05)
3.5	H	81.84	24.34	528.67	23.50 (+01)
4.0	I	81.70	24.19	496.67	22.07 (-06)
4.5	J	81.16	24.04	460.00	20.44 (-13)
5.0	K	80.16	23.75	390.00	17.32 (-26)

[a]The values in parenthesis indicates the percentage increase or decrease of compressive strength with respect to reference mix

Tensile strength is obtained by using a cylindrical specimen of 150mm diameter and 300mm height after 28 days of curing for different percentages of flyash, mocrosilica and steel fibers along with 15% redmud. The same results are presented in table 5, 6 and 7 respectively for various percentages of flyash, mocrosilica and steel fibers along with 15% redmud.

Table 5. Experimental test results on Tensile Strength of waste plastic FRC with different flyash percentage.

Flyash (%)	Specimen	Failure load (kN)	Tensile strength(MPa)
0 (Ref mix)	A	226.67	3.20
05	B	230.00	3.25 (+2)[a]
10	C	233.34	3.29 (+3)
15	D	226.67	3.20 (+0)
20	E	225.00	3.18 (-1)
25	F	218.34	3.08 (-4)

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[a]The values in parenthesis indicates the percentage increase of tensile strength with respect to reference mix

Table 6. Experimental test results on Tensile Strength of waste plastic FRC with different Microsilica percentage.

Microsilica(%)	Specimen	Failure load (kN)	Tensile strength (MPa)
0 (Ref mix)	A	270.00	3.81
02	B	273.34	3.86 (01)[a]
04	C	286.67	4.05 (06)
06	D	300.00	4.24 (11)
08	E	320.00	4.52 (19)
10	F	340.00	4.81 (26)
12	G	300.00	4.24 (11)

[a]The values in parenthesis indicates the percentage increase or decrease of compressive strength with respect to reference mix

Table 7. Experimental test results on Tensile Strength of waste plastic FRC with 15% Redmud and different Fiber percentage.

Fibres (%)	Specimen	Failure load (kN)	Tensile strength (MPa)
0 (Ref mix)	A	163.34	2.30
0.5	B	166.67	2.35 (+02)[a]
1.0	C	173.34	2.44 (+06)
1.5	D	186.67	2.63 (+14)
2.0	E	200.00	2.82 (+23)
2.5	F	193.34	2.68 (+17)
3.0	G	176.67	2.49 (+08)
3.5	H	146.67	2.07 (-10)
4.0	I	123.34	1.73 (-25)
4.5	J	110.00	1.55 (-33)
5.0	K	93.34	1.31 (-43)

[a]The values in parenthesis indicates the percentage increase or decrease of tensile strength with respect to reference mix

Concrete specimens of dimensions 100mm x 100 x 500mm are used to obtain the flexural strength after 28 days of curing for different percentages of flyash, mocrosilica and steel fibers along with 15% redmud. Flexural strength values for various percentages of flyash, mocrosilica and steel fibers along with 15% redmud are presented respectively in table 8, 9 and 10.

Table 8. Experimental test results on Flexural Strength of waste plastic FRC with different Flyash percentage.

Flyash (%)	Specimen	Failure load (kN)	Flexural strength(MPa)
0 (Ref mix)	A	12.47	4.98
05	B	13.00	5.20 (+04)[a]
10	C	14.40	5.76 (+16)
15	D	13.67	5.46 (+10)
20	E	12.74	5.09 +02)
25	F	11.00	4.40 (-12)

[a]The values in parenthesis indicates the percentage increase or decrease of flexural strength with respect to reference mix

Table 9. Experimental test results on Flexural Strength of waste plastic FRC with different Microsilica percentage.

Microsilica(%)	Specimen	Failure load (kN)	Flexural strength (MPa)
0 (Ref mix)	A	13.80	5.53
02	B	14.00	5.58 (1)[a]
04	C	14.30	5.66 (2)
06	D	14.26	5.70 (3)
08	E	14.43	5.77 (4)
10	F	14.70	5.88 (6)
12	G	14.26	5.70 (3)

[a]The values in parenthesis indicates the percentage increase or decrease of compressive strength with respect to reference mix

Table 10. Experimental test results on Flexural Strength of waste plastic FRC with 15% Redmud and different Fiber percentage.

Fibres (%)	Specimen	Failure load (kN)	Flexural strength (MPa)
0 (Ref mix)	A	10.13	4.05
0.5	B	10.93	4.37 (+08)[a]
1.0	C	11.74	4.69 (+16)
1.5	D	12.8	5.12 (+26)
2.0	E	13.53	5.41 (+34)
2.5	F	13.34	5.33 (+32)
3.0	G	12.80	5.12 (+26)
3.5	H	12.27	4.90 (+21)
4.0	I	11.20	4.48 (+11)
4.5	J	09.87	3.94 (-03)
5.0	K	08.54	3.41 (-16)

[a]The values in parenthesis indicates the percentage increase or decrease of flexural strength with respect to reference mix

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Table 11. Experimental test results on Impact Strength of waste plastic FRC with different Flyash percentage.

Flyash (%)	Specimen	Number of blowsto cause		Impact strength (N-m)to cause	
		First crack	Final failure	First crack	Final failure
0 (Ref mix)	A	A	5.33	14.33	53.72
05	B	B	5.66	17.33	57.05 (+06)
10	C	C	6.67	22.66	67.23 (+25)
15	D	D	4.33	21.66	43.64 (+19)
20	E	E	4.00	15.00	40.32 (+25)
25	F	F	3.66	10.66	36.89 (+31)

[a]The values in parenthesis indicates the percentage increase or decrease of impact strength with respect to reference mix

Table 12. Experimental test results on Impact Strength of waste plastic FRC with different Microsilica percentage.

Microsilica(%)	Specimen	Number of blowsto cause		Impact strength (N-m) to cause	
		First crack	Final failure	First crack	Final failure
0 (Ref mix)	A	04.34	19.34	052.77	235.17
02	B	04.67	22.67	056.78 (08)	275.66 (17)
04	C	05.00	23.34	060.80 (15)	283.81 (21)
06	D	06.67	24.67	081.10 (54)	299.98 (28)
08	E	08.67	26.67	105.54 (100)	324.30 (38)
10	F	10.34	30.67	125.73 (138)	372.94 (59)
12	G	07.00	27.00	085.12 (162)	328.32 (40)

[a]The values in parenthesis indicates the percentage increase or decrease of compressive strength with respect to reference mix

Table 13. Experimental test results on Impact Strength of waste plastic FRC with 15% Redmud and different Fiber percentage.

Fibres (%)	Specimen	Number of blows to cause		Impact strength (N-m) to cause	
		First crack	Final failure	First crack	Final failure
0 (Ref mix)	A	13.33	17.00	079.98	102
0.5	B	15.00	21.66	090.00 (13)	130
1.0	C	17.66	23.66	105.96 (32)	142
1.5	D	20.66	27.66	123.96 (55)	166
2.0	E	24.66	32.33	148.00 (85)	194
2.5	F	19.66	27.67	117.96 (47)	166
3.0	G	18.67	25.34	112.00 (40)	152
3.5	H	17.00	20.33	102.00 (28)	122
4.0	I	15.66	19.66	094.00 (18)	118
4.5	J	14.66	17.00	088.00 (10)	102
5.0	K	12.33	15.66	704.00 (-8)	094

[a]The values in parenthesis indicates the percentage increase or decrease of compressive strength with respect to reference mix

Workability of concrete is represented in terms of slump value, compaction factor and percentage flow. Table 14, 15 and 16 respectively indicates the workability of concrete for various percentages of flyash, mocrosilica and steel fibers along with 15% redmud.

Table 14. Experimental results on workability of concrete usingwaste plastic FRC with different Flyash percentage.

Flyash (%)	Slump (mm)	Compaction factor	Percentage flow
0 (Ref mix)	0	0.87	12.38
05	0	0.83	12.53
10	0	0.89	11.02
15	0	0.86	11.67
20	0	0.83	10.91
25	0	0.84	10.05

Table 15. Experimental results on workability of concrete using waste plastic FRC with different Microsilica percentage

Microsilica(%)	Slump (mm)	Compaction factor	Percentage flow
0 (Ref mix)	0	0.80	07.50
02	0	0.84	09.00
04	0	0.84	12.30
06	0	0.85	13.30
08	0	0.86	14.20
10	0	0.86	16.25
12	0	0.84	13.00

Table 16. Experimental results on workability of concrete using waste plastic FRC with 15% Redmud and different Fiber percentage.

Fibres (%)	Slump (mm)	Compaction factor	Percentage flow
0 (Ref mix)	0	0.92	5.6
0.5	0	0.91	5.6
1.0	0	0.91	5.5
1.5	0	0.91	5.5
2.0	0	0.91	5.3
2.5	0	0.91	5.3
3.0	0	0.90	5.0
3.5	0	0.90	5.0
4.0	0	0.89	4.6
4.5	0	0.89	4.4
5.0	0	0.89	4.1

Following are the some of observation based on experimental results:

1. It is observed that, the waste plastic FRC shows an increase in the strength properties such as compression, tension, flexure and impact upto an addition of 10% of flyash and microsilica into it. Further increase in percentage causes decrease in strength.

Thus, the waste plastic FRC shows a higher strength properties when 10% flyash and 10% of microsilica is added and the percentage increase in the compressive strength, tensile strength, flexural strength and impact strength is 13%, 3%, 16%, 25% and 58% respectively in case of 10% addition of flyash and the percentage increase in the compressive strength, tensile strength, flexural strength and impact strength is 55%, 26%, 6%, 138% and 59% respectively in case of 10% addition of microsilica.

This may be due to the fact that, optimum workability is achieved for 10% of flyash and microsilica which results in thorough compaction and higher strengths. Also, most of the cavities may get filled by using 10% of flyash and microsilica, resulting in right pozzolonic reaction. Thus, it can be concluded that higher strength properties in waste plastic FRC is observed in mixes with10% of flyash and microsilica.

2. It is observed that the maximum workability is achieved with 10% of flyash and microsilica, further increase in percentage of admixtures decreases workability. Addition of microsilica above 10% makes the concrete stiffer as flyash and microsilica may act as ball bearings resulting in less friction and more workable concrete. Thus it can be concluded that, in waste plastic FRC 10% of flyash and microsilica yield good workability.
3. It has been observed that the strength properties such as compressive strength, tensile strength, flexural strength and impact strength of waste plastic fibre reinforced concrete with 15% redmud increases as the percentage of fibres in it increases up to 2%. The addition of fibres beyond 2% will decrease the strength properties of waste plastic fiber reinforced concrete i.e. the waste plastic fibre reinforced concrete with redmud shows maximum strength properties when 2% fibres are used. Therefore, the higher strength properties can be achieved with the addition of 2% of waste plastic fibres and 15% redmud (by weight cement) and the percentage increase in the compressive strength, tensile strength, flexural strength and impact strength is 23%, 23%, 34%, 47% and 90% respectively.
4. It has been observed that the workability of waste plastic fiber reinforced concrete decreases as the percentage of fibres in it increases.
5. This is obviously because of less flow of concrete with more fibre content. Thus it can be concluded that as the percentages of waste plastic fibres increase the workability decreases.

5. Conclusions

Based on the experimental results the following conclusions were made

1. It can be concluded that with the addition of 10% flyash, 10% microsilica, and 15% redmud with 2% addition of fibres will results in higher strength and good workability properties for waste plastic FRC. Further increase in percentage of waste plastic fibres reduce the workability characteristics of waste plastic FRC.
2. Thus flyash, microsilica and redmud can be used in the production of waste plastic fibre reinforced concrete as a composite material.

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